Laser-Produced Plasmas of Tin-Gold Alloy for EUV Sources

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1. Introduction

Based on Cowan code [1] calculations, the strong UTAs of tin (Sn) centre near 13.5 nm wavelength while for gold (Au), the UTA emission stretches from 10 – 20 nm depending on the Au ion stages involved in the emission. Targets containing Sn are candidates for EUV radiation sources for next generation of lithography in semiconductor industries.

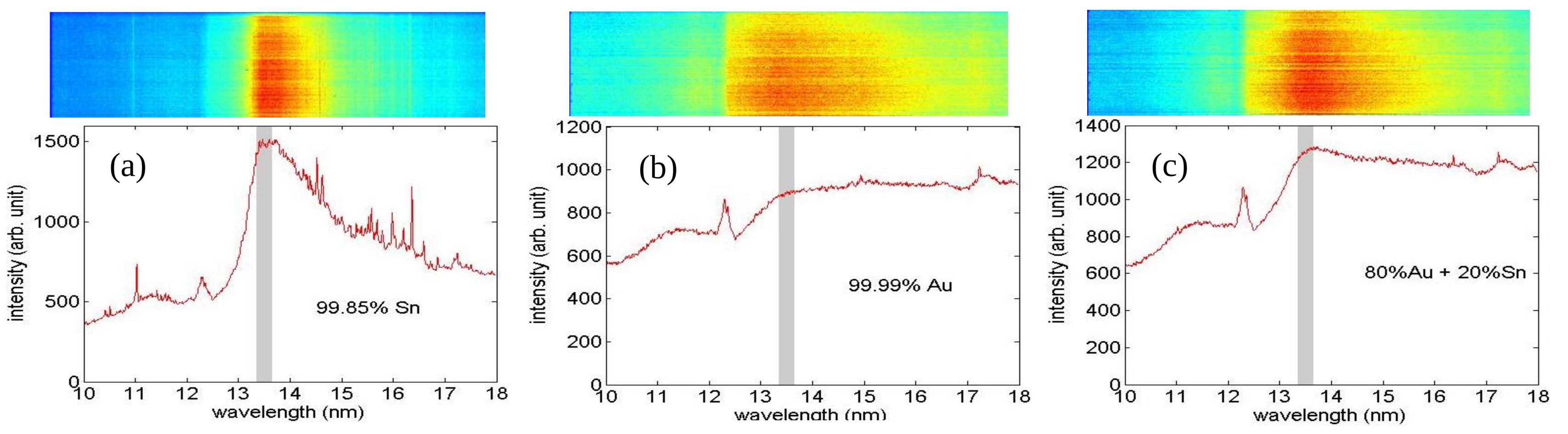

Figure 2: *Examples of spectrum of (a) pure tin, (b) pure gold and (c) 80%Au – 20%Sn alloy captured by Jenoptik spectrograph.*

2. Experimental set up

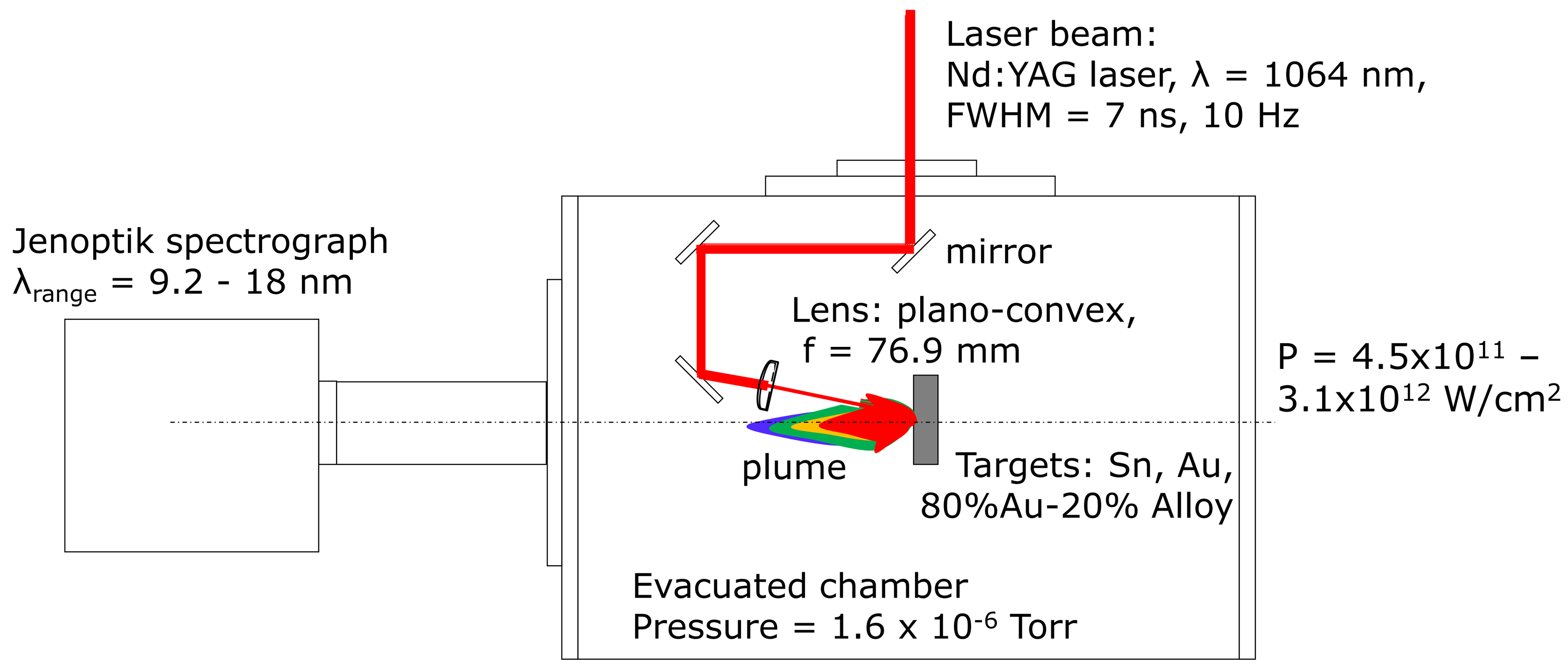

Figure 1: *Schematic experimental set up used in this investigation.*

3. Results

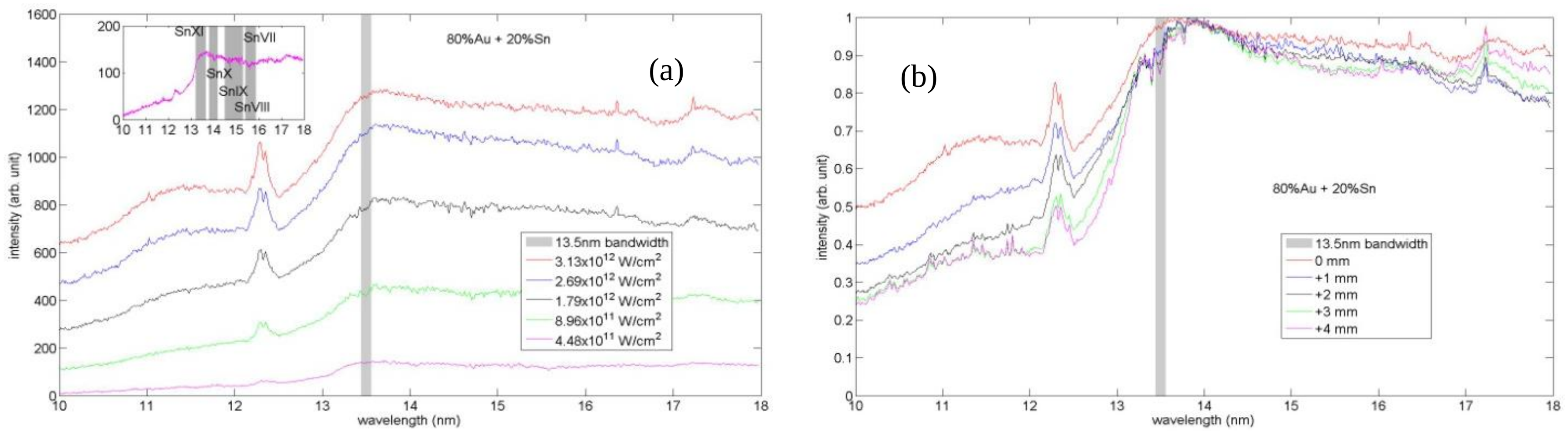

Figure 3: *Spectra of SnAu alloy at (a) different power densities, and (b) different lens focusing conditions.*

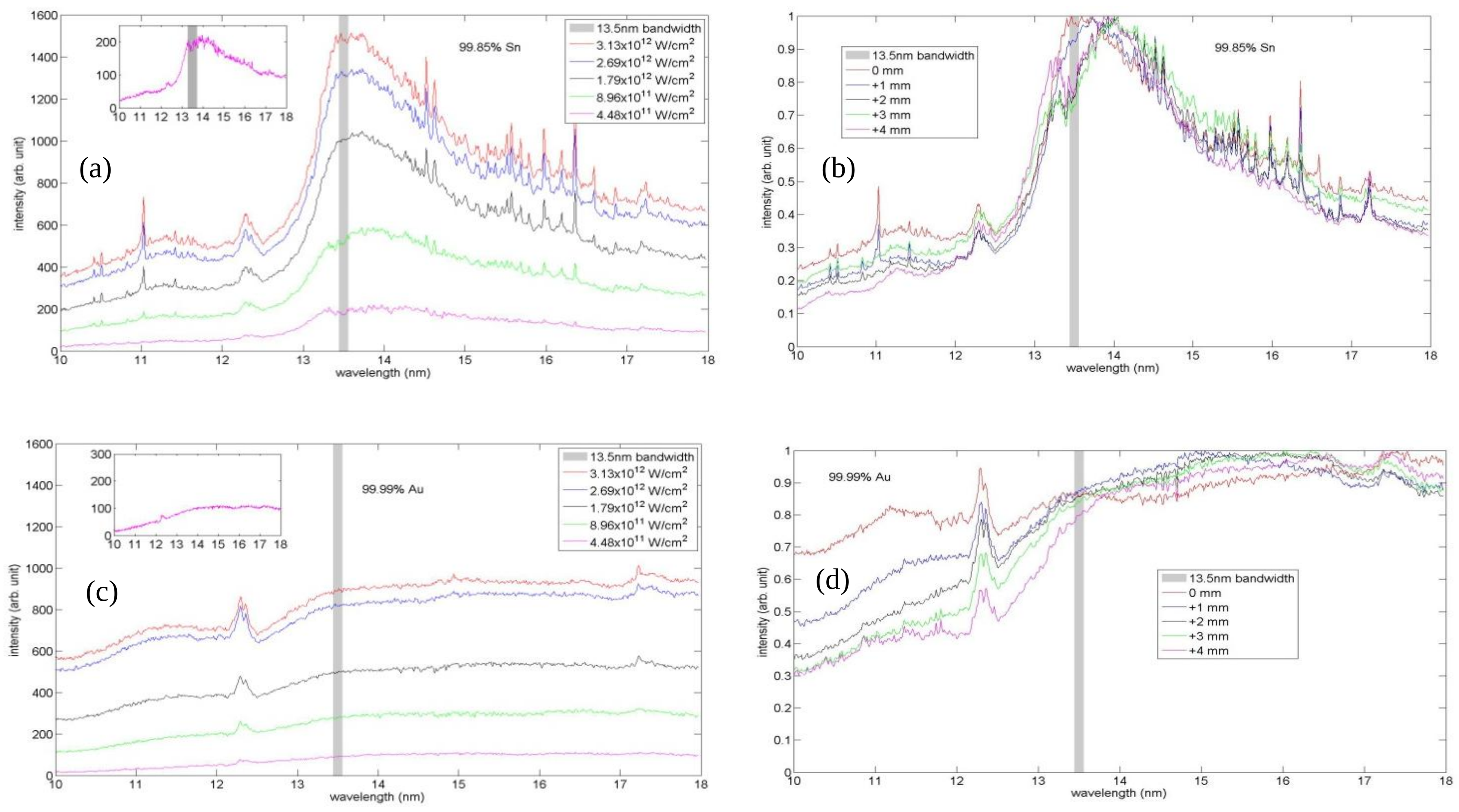

Figure 4: *(a) Sn spectra at different power densities (b) Sn spectra at different lens focusing conditions (c) Au spectra at different power densities (d) Au spectra at different lens focusing conditions .*

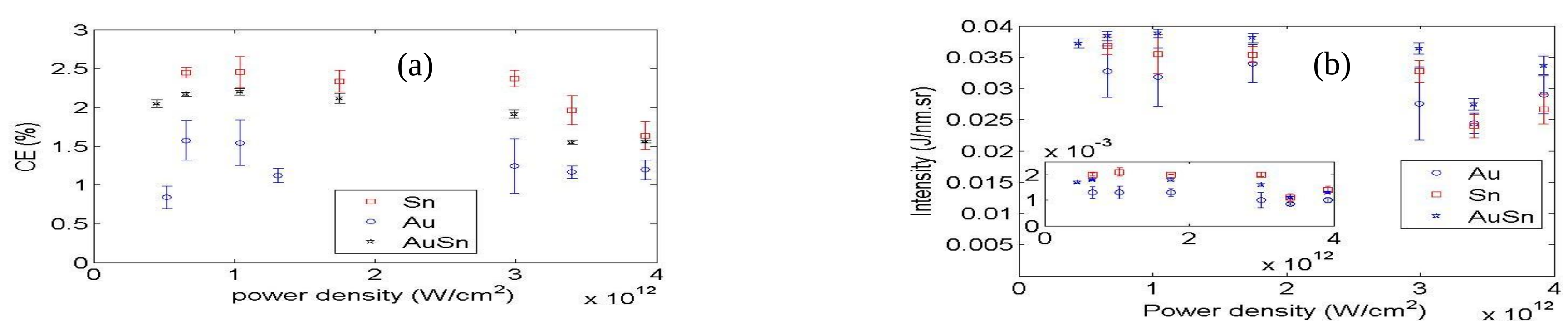

Figure 5: *(a) In-band conversion efficiency (CE) of pure Sn (red squares), pure Au (blue circles) and SnAu alloy (black pentagrams). (b) Out-of-band-intensities of pure Sn (red squares), pure Au (blue circles) and SnAu alloy (black pentagrams) compared to their in-band intensities (inset).*

4. Discussion

The experimental results (fig. 3(a,b)) indicate that the EUV radiation emitted by the LPP of SnAu alloy is observed at all wavelength ranges, though it peaks around 13.5 nm. The spectra at wavelengths longer than 14 nm are nearly flat while the emission is less intense at shorter wavelengths. Self-absorption features are also observed at low power densities (fig. 3(a), inset) particularly due to lower ion stages of tin ranging from Sn VII – Sn X.

From pure tin target spectra (fig. 4(a-b)) one can clearly see that maximum Sn EUV emission is centred around 13.5 nm. There is no significant difference in the EUV spectra at higher power densities, though self absorption features become apparent at lower power densities (fig. 4(a), inset).

Compared to the SnAu alloy, the pure tin target gives more pronounced self absorption features and the absorption by Sn XI is observed in the pure tin target while this feature is not obvious in the SnAu alloy target.

The strong discrete lines in the pure tin spectra at longer wavelength (between 14.5 – 17 nm) are due to higher ion stages of tin ranging from Sn XVII – Sn XXII [2]. As for the pure gold target, the nearly flat spectra (fig. 6(c-d) are due to high electron temperatures produced in the experiments which result in high ion stages (theoretically up to Au XXV) that emit EUV radiation from primarily open 4d and 4f subshells [3].

Overall, the alloy of tin and gold helps reduce self absorption features but doesn't increase the in-band CE and intensity compared to pure tin (fig. 5(a-b)). The maximum CEs for pure Sn, Au and SnAu alloy are 2.45%, 1.61% and 2.20% respectively.

5. Conclusion

The EUV emission of SnAu alloy LPP is observed at all wavelength ranges, though it peaks around 13.5 nm. Self absorption features due to tin lower ion stages are more pronounced in pure tin than in tin-gold alloy, however the alloy does not help increase the in-band conversion efficiency.

Future work

1. Laser-produced plasmas of some other materials .
2. Time resolved-spectroscopy for different time windows/gates.
3. Spatial and angular emission spectroscopy.
4. Spatial confinement to enhance CE.

References

[1] R. D. Cowan, "*The theory of atomic structure and spectra*". University of California Press (1981).
[2] C. Suzuki, et al. ''*Analysis of EUV spectra of SnXIX-SnXXII observed in low-density plasmas in the Large Helical Device*". J. Phys. B: At. Mol. Opt. Phys. 43 (2010) 074027.
[3] M. Finkenthal et al. *"Soft X-ray bands of highly ionized tungsten, gold and lead emitted by the TEXT tokamak plasma"*. Physics Letters A. Volume 127 (1988) 255-258.

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